Lower Colorado River Multi-Species Conservation Program

Balancing Resource Use and Conservation

Survival of Razorback Sucker Stocked into the Lower Colorado River Final 2006 Annual Report

U.S. DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

August 2007

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Lower Colorado River Multi-Species Conservation Program

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Lower Colorado River
Multi-Species Conservation Program Office
Bureau of Reclamation
Lower Colorado Region
Boulder City, Nevada
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August 2007

Survival of razorback sucker stocked into the lower Colorado River

Final 2006 Annual Report

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between
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and
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Executive Summary

Portions of the lower Colorado River from Parker Dam downstream to Imperial Dam were surveyed during the period January 2006 to December 2006 for the presence of razorback sucker *Xyrauchen texanus*. The study area included the main river channel and all confluent, watercraft-accessible backwaters and side channels in La Paz and Yuma counties in Arizona, and San Bernardino, Riverside, and Imperial counties in California. Methods were boat electrofishing and trammel netting that resulted in contact with a total of 12,613 fish representing at least 18 species including 606 individual razorback suckers accounting for 5.3% of the total catch. About a third (229) of the razorbacks suckers were recaptured fish, with a time-at-large ranging from 14 to 565 days. All razorback suckers are thought to have been repatriated (stocked) fish. Mean total length was 37.9 cm (range 28.3 – 62.0). Sex ratio was 83 female, 178 male, 288 juvenile, and 57 unknown.

In an attempt to estimate abundances of flathead catfish in A-7 and A-10 backwaters in Arizona, monofilament gill nets (43 m x 3 m x 10.2 cm mesh) and "jug lines" (A-10 only, hooks baited with bluegill sunfish, stabilized with sinkers, and tethered to milk jugs in littoral areas) were deployed in September and October 2006. Two flathead catfish were captured in A-10 and one flathead catfish was captured in A-7. Flathead catfish abundance in both backwaters appeared low.

To evaluate possible seasonal and local trends in avian predation on stocked razorback suckers, monitoring data from January 2003 to December 2006 were queried for notations that suggested wounds associated with avian attacks. Evidence implicating avian predation was found to be seasonal with higher frequencies in winter months, presumably due to increased abundance of migratory avian piscivores. Fish captured in A-10 backwater had a lower frequency wounds than A-7, and avian predation overall has declined from 2003 to 2006, possibly as a result of shifting stocking to A-10. Repatriate vulnerabilities may be causally linked to surface habituation as a result of surface feeding at hatcheries. Surface netting paired with a mathematical model were applied in 2006 to examine depth preference of stocked fish. Experimental subsurface feeding was initiated at Bubbling Ponds, with results pending in 2007.

Adult razorback sucker (45 - 55 cm long) were implanted with telemetric tags to assess survival and dispersal between two contrasting stocking sites (A-10 and A-7 backwaters) along the lower Colorado River, Arizona and California. Twenty-four fish were fitted with ultrasonic transmitters and half was stocked into each of the two backwaters. A-10 is intermittently connected via culvert with main channel and has steep banks while A-7 is permanently connected via channel to the main river and has shallow shorelines. After one year, no fish dispersed from A-10. However, six of 12 fish exited A-7, all between 20 and 50 days post stocking. Additionally, the fish that left A-7 were contacted only in the main river channel, and despite extensive surveys none was found in any other backwater. Unlike dispersal, survival was comparably low in both habitats: in each of A-10 and A-7, six of 12 fish (50%) were confirmed dead and tags were recovered within the backwater. Remaining fish in A-10 were contacted periodically throughout the study, and two were contacted on every survey. In contrast, the fate of the six remaining individuals that dispersed from A-7 is unknown. While ultimate levels of confirmed mortality were similar for both release sites *within* backwaters, extensive dispersal (50%) and loss from the system of all A-7 fish may advise against the suitability and continued use of A-7 as a razorback sucker stocking site. When only dispersal is considered, the minimum number of surviving fish within a backwater declined faster in A-7 than A-10.

Introduction

Razorback suckers have been repatriated to the lower Colorado River for more than 30 years, and prior to 2000, fish were stocked at a variety of locations along the lower river (Minckley et al. 1991; Schooley & Marsh In press). Stocking was accelerated after 2000 to meet requirements of a U.S. Fish and Wildlife Service Biological Opinion of lower river operations (USFWS 1997), and more recently the mandates of the Lower Colorado River Multi-Species Conservation Plan (MSCP 2004 a-c). Arizona State University has monitored the newly stocked razorback sucker population and assessed the stocking program as a whole since 2003.

For the first three years of study, intensive, opportunistic surveys that targeted razorback suckers were conducted along approximately 282 km of river from Parker Dam downstream to Yuma. Multiple samples were collected from the main channel and all watercraft-accessible backwaters and side channels. Long-term survivorship was undetectable over the study period, and few population estimates were available due to a lack of recaptures (Schooley et al. 2004, 2006).

Monitoring activities continued through 2006 as the first year of a new, multi-year agreement that included an expansion of research on factors affecting mortality and dispersal. This report summarizes activities in 2006 under the new agreement. Monitoring has continued to show a lack of long-term survival or retention of razorback suckers stocked in the lower Colorado River below Parker Dam.

Eight interim monitoring trip reports have been submitted to U.S. Bureau of Reclamation (USBR) in the past year (Table 1). These are incorporated here by reference and are not otherwise included in this document.

Study Area

The survey area for this project includes 282 km of lower Colorado River (LCR) main river channel, backwaters, side-channels, reservoirs, and floodplain lakes between Parker Dam at river mile (RM)[1] 192 and Laguna Dam at RM 43.5. This reach of the LCR is partitioned into six USBR administrative divisions (Appx. 1). Because of permitting issues, the primary study area excluded waters within the boundaries of the Colorado River Indian Tribes (CRIT), approximately located between RM 180 and 125, Parker Division.

From 2000 through 2004, razorback suckers were consistently stocked into A-7 backwater (Table 2 & Appx. 1, Map 1). In February 2005, additional stockings into A-10 backwater were initiated (Appx. 1, Map 2). Both backwaters are within a previously defined “stocking zone” (Schooley et al. 2006, Appx. 1, Maps 3 & 4). The stocking zone is located in the Palo Verde Division between the southern boundary of the CRIT and C-10 backwater, a reach of 24.4 km (15.25 RM). The zone includes six named backwaters (A-7, A-10, C-3, C-5, C-7, and C-10) and three unnamed backwaters. This area has been the location of the great majority of razorback sucker captures since our monitoring began. In September 2006, stocking began at an additional site- the Parker Strip (RM

[1] River miles are measured upstream from the Southerly International Boundary near San Luis, Arizona.

178-192) located upstream and outside of the stocking zone (Map 5). This is the first major stocking outside the stocking zone since monitoring began, although U.S. Fish and Wildlife Service (USFWS) has conducted a few stockings of razorback sucker salvaged from Cibola High Levee Pond or Imperial Ponds (formerly Ducks Unlimited Ponds).

Methods

Post Stocking Monitoring and Assessment

Surveys in 2006 were concentrated in backwaters and main river channel of the stocking zone, although surveys were also conducted in locations of previous razorback sucker captures outside the stocking zone. Notable localities include the Palo Verde Outfall Drain, located in the Cibola Division (Map 6), which is the first major off-channel habitat 49.6 km (31 RM) down-river from the stocking site, Imperial National Wildlife Refuge including Martinez Lake (RM 56, Map 7), Parker Strip, and three small backwaters (<1 ha total) located at RM 99-100 (Map 8). These small backwaters comprise the only off-channel habitat between the stocking zone and the Palo Verde Outfall Drain, possibly providing a valuable intermediate area for fish occupation between the two localities.

Primary sampling methods were boat electrofishing and trammel netting. Electrofishing (Smith-Root SR-18H package with GPP 7.0 pulsator) was conducted during evening and nighttime. Habitat was visually inspected and selected physical and chemical parameters were sporadically measured for the main channel and backwaters[2]. Navigational notes and information on access were recorded for future reference.

Trammel nets (46 x 1.8 m x 3.8 cm mesh) typically have been set in the evening, fished overnight, and retrieved the following day. During 2006, nets were set and retrieved the same evening in areas of higher razorback sucker concentrations to reduce sampling related fish stress and potential for mortality. Net set locations were chosen based on water depth (>1.5 m) and habitat (proximal to cover but free of submerged obstacles or

[2] Water depth and temperature were measured with on on-board Garmin GPS-sonar, and dissolved oxygen, pH, and electrical conductivity were determined using a Eureka multi-parameter probe.

debris). Net sites generally were in backwaters off the main channel. Nets were intentionally set in remote, slightly inaccessible locations to avoid watercraft traffic. Nominal time for setting and removing nets varied over a range of times depending on daylight cycles and catch.

All fish were identified to species when possible and counted by method of capture and life stage (0 or 1). Age "0" was used to indicate small-bodied species (such as threadfin shad, mosquitofish, and mollies) and young-of-year for large-bodied species, while Age "1" indicated subadult to adult, large-bodied fish.

When applicable, native fish were individually measured (total length [TL], in cm), scanned for wire tag (WT) and passive integrated transponder (PIT) tag, sexed (male, female, juvenile, and unknown [for fish ≥ 40 cm for which gender could not be reliably determined]), and examined for general health and condition. A PIT tag was implanted into the abdominal cavity of natives if none was present, and all fish were released near the site of capture.

Voucher specimens up to a total of 10 individuals per non-native species[3] were fixed in 10% formaldehyde prior to rinsing and preservation in 70% ethanol, and deposited into the ASU Collection of Fishes (Table 3). Exceptional individuals and others exhibiting key characteristics or other features were photographed to provide a permanent record.

As a surrogate for fish density, catch per unit effort (CPUE) was used to graphically examine abundance across USBR administrative divisions. Standardized units of effort were number of fish captured per 1,000 seconds electrofishing, and number of fish captured per 100 m^2 of trammel net.

Repeated surveys conducted in the stocking backwaters (A-7 and A-10) as well as backwaters within the stocking zone were used to evaluate and compare dispersal and potential mortality of stocked razorback suckers. For analysis, catch data were tabulated for each stocking location: A-10 Upper, A-10 Lower, and A-7. Because A-7 is permanently open to the river, catch data for A-7 included both A-7 proper plus other backwaters and habitats within the stocking zone. C-10 and the three unnamed

[3] This represents the total number of vouchers collected in 2006.

backwaters were excluded from the analysis due to limited connectivity with the main channel (C-10) or sporadic sampling (unnamed backwaters). Although each half of A-10 is periodically isolated from the main channel, some razorback suckers have dispersed out of A-10 (Schooley et al. 2007). Thus, any fish known to have originated in A-10 (PIT tag number or wire tag location) and subsequently caught outside of A-10 were removed from this analysis. Finally, fish that were released into A-10, were later captured but did not contain a wire tag, and were not PIT tagged upon release may be incidentally included in the A-7 data set. That is, in some cases in which no PIT or wire tag was detected, fish from A-10 may have been attributed to A-7 stocking events.

Piscivorous fishes

Independent of routine monitoring efforts for razorback sucker, A-10 and A-7 backwaters were surveyed for presence of large fish predators, specifically flathead catfish. Regular monitoring with trammel nets and electrofishing indicated low abundance of flathead catfish in both upper and lower sections of A-10, and relatively higher abundance in A-7. In an attempt to estimate abundances of flathead for each backwater, monofilament gill nets (43 m x 3 m x 10.2 cm mesh) and “jug lines” (A-10 only, size 6/0 hooks baited with bluegill sunfish, stabilized with 85 gram sinkers, and tethered to empty, sealed milk jugs in littoral areas of variable depth) were deployed in September and October 2006. Nets and jugs were checked twice daily but fished consistently and bait was replaced as needed. Large flathead catfish were weighed (kg) measured (TL in cm), scanned for PIT tags and metal objects, and marked by means of a copper Decker’s’ Hump® Hog Ring attached to the lower lip through the dentary bone.

Avian predation

To evaluate possible seasonal and local trends in avian predation on stocked razorback suckers, monitoring data from January 2003 to December 2006 were queried for notations that suggest wounds associated with avian attacks. In general these markings included vertical scratches or punctures consistent with beaks or talons. All putative attacks were contextually analyzed to exclude markings possibly due to fish predation or capture stress. Remaining notations were grouped by capture location and month.

Seasonal trends were graphically interpreted from changes in proportion of catch (% of catch with such notations suggesting avian predation). Proportions of catch were compared across years and statistically analyzed with a Chi Square Homogeneity test. Captures in A-10 backwater were compared with both A-7 backwater and all other capture locations combined. Chi Square Homogeneity tests were used to evaluate statistical significance where inspection suggested there were differences in proportion of catch between capture locations (Yates' correction applied only for 2x2 contingency tables; Moore & McCabe 2003).

To evaluate preference of fish for position in the water column, a unique trammel netting methodology was utilized. Each of two, 43 m x 1.83 m x 3.8 cm-mesh trammel nets was labeled lengthwise at 1 m intervals. One net was modified to float at the surface, while the other was allowed to sink. Nets were set in waters ≥1.8 m deep for variable periods and with the aid of a portable Hummingbird® depth finder. Surface water temperature was recorded in °C for each net, and water depth was recorded at 10-m horizontal intervals along the net, from origin to terminus: d_0, d_{10}, d_{20}, d_{30}, and d_{43}. Upon net retrieval, razorback suckers were extracted, location in the net noted as horizontal distance (H_d, m from origin) and vertical distance (V_d, m from bottom of net). All fish were scanned for PIT tag, measured for total length (TL) in cm, sexed, and condition was noted (excellent, good, fair, or poor). Fish history was evaluated for each PIT tagged fish and days since stocking (t_s) was calculated. For captured fish that did not contain a PIT tag, it was assumed that the fish originated from the most recently stocked batch of non-PIT tagged fish at the nearest stocking site.

A mathematical model was utilized to calculate a standardized depth index (DI) for each fish. Variables incorporated into the model were distance from surface (d_{surf}), distance from substrate (d_{sub}) and actual water depth (d_t) at the fish entanglement location. DI standardizes all possible water depths and is an integer between -1 and +1, representing the substrate and surface, respectively. The model essentially divides each net into four parallelograms, bounded by the vertical lines at d_i and d_j and the horizontal float and lead lines. A fish's position in the water column is simply calculated through geometry. The model is adaptive and takes into account if the water is getting deeper or shallower at each $d_{i,j}$, as this affects the appropriate calculations of relative depth (*i* and *j* are subscript variables that represent the designations for *d*-sub 0,10,20,30,43; see below). Finally, the model assumes that the entanglement site represents the fish's actual depth in the water column at the time of contact with the net. Net sections are assumed linear, and topographical features between $d_{i,j}$ readings are negligible.

Formulas:

$$DI = \frac{d_{sub} - d_{surf}}{d_t}$$

	Water is getting deeper $d_j > d_i$	Water is getting shallower $d_i > d_j$
Floating Net	$d_{surf} = 1.83 - V_d$ $d_{sub} =$ $d_j - \left[(j - H_d) \times \frac{(d_j - d_i)}{j - i}\right] - (1.83 - V_d)$	$d_{surf} = 1.83 - V_d$ $d_{sub} =$ $d_i - \left[(j - H_d) \times \frac{\lvert d_j - d_i \rvert}{j - i}\right] - (1.83 - V_d)$
Sinking Net	$d_{surf} = d_i - \left[(H_d - i) \times \frac{(d_j - d_i)}{j - i}\right] - V_d$ $d_{sub} = V_d$	$d_{surf} = d_j - \left[(j - H_d) \times \frac{\lvert d_j - d_i \rvert}{j - i}\right] - V_d$ $d_{sub} = V_d$

$j > i$ (i = 0, 10, 20, or 30, j = 10, 20, 30, or 43, i and j are sequential)

Model output will be analyzed to determine if 1) stocked fish spend a disproportionate amount of time near the surface, 2) any correlative relationships exist between time since stocking, fish condition, water temperature, time of day, and fish depth preference, and 3) if surface habituation can be reversed by hatchery subsurface feeding.

To investigate surface habituation, 92 razorback suckers (lot code 5WBF1P) at Bubbling ponds State Fish Hatchery (Cornville, AZ), were captured on September 2, 2006 from a pond with a cast net and 60-cm diameter, baited hoop nets, both of 0.6-cm mesh. Fish were measured for TL and randomly divided equally into two concrete raceways 1.52 m wide x 7.32 m long x 0.91 m deep filled to 0.8 m with spring water for a total capacity of 8.9 m^3. Raceways were fitted with automatic belt feeders that distributed approximately 0.45 kg of 0.4 cm diameter pellet food over 8 hrs. Fish were fed an oxytetracycline medicated diet for 14 days, after which regular non-medicated food was utilized. Each raceway was equipped with a 1 m length of 38.1 cm inside diameter PVC pipe situated vertically and mounted at the water's surface (Fig. 1). The bottom of the pipe was screened to prevent fish entry. In one raceway (experimental) the food was delivered into the pipe, which prevented consumption at the surface. In the other raceway (control) the food was delivered to the surface in front of the pipe, mimicking regular surface feeding. Raceways were equipped for underwater digital imagery. Images were taken at intervals during daytime and fish behavior was compared between the treatments to investigate differences in swimming depth as a possible effect of subsurface feeding. Fish were maintained with daily feeding and raceways were cleaned up to twice weekly. After 49 days, fish were starved for four days to observe depth behavior in the absence of food. This was intended to mimic an absence of surface feeding after fish stocking. Fish were then measured for TL, weighed (g), and returned to rearing ponds.

To investigate surface habituation in rearing ponds, a subsurface feeding exclosure was constructed and deployed in a hatchery rearing pond on October 25, 2006. The exclosure consisted of a 2.4 m wide x 3.5 m long x 1.83 m deep frame of 5 cm PVC pipe lined with 2.54 cm hexagonal mesh, galvanized steel poultry netting. The exclosure floats at the surface of the pond and is tethered in place (Fig. 2). Food pellets are manually distributed into the frame and fish are unable to consume the food until it sinks through the exclosure to a depth of 1.83 m. The pond with the feeding exclosure served as an experimental stock while a nearby pond of similar year class fish served as the control and were surface fed. Fish were be stocked in January 2007 and future, post-stocking monitoring will analyze fish depth preference, differential survival, and evidence of avian predation.

Sonic and Radio Telemetry

Sonic telemetric tags were used to track movement and dispersal of razorback sucker. Adult fish (n = 24) ranging from 42.5 cm to 54.1 cm total length (mean TL = 47.5 cm) were selected from a regular stocking event and implanted with tags. We used ultrasonic transmitters model AT-M-12-I (Sonotronics, Inc., Tucson, Arizona). Each cylindrical device measured 16 x 64 mm, transmitted a uniquely identifiable four digit code, and had an approximate lifespan of one year. Additionally, tags were equipped with a motion sensing capability that lowered the ping interval by 50 ms/h when no movement was detected. After 24 hours, the ping interval decreased by 1200 ms and aided the recovery of dead fish or shed tags. If the tag moved subsequently the ping interval was reset to normal.

Telemetry tags were surgically implanted at each release site (A-7 or A-10) as described in Mueller et al. (2000). After surgery, fish were allowed to recover for several minutes in a protected net enclosure prior to release. Twelve fish were released in each backwater on January 22, 2006. After release, surveys for telemetric tags were conducted using two boat-mounted directional hydrophones model DH-4 and ultrasonic receiver USR-96 provided by the tag manufacturer (Sonotronics, Inc.). In order to recover tags of suspected mortalities, we used a hand-held underwater receiver (model UDR) with headphones.

Initially, surveys were conducted daily for five days post release. After the first week surveys were conducted twice monthly for the first three months, then monthly thereafter through December 2006. For each survey, the release backwater was surveyed first followed by the main channel Colorado River plus any connected backwater habitats accessible to fish. The entire main channel from Palo Verde to Imperial dams was surveyed at least once. All fish contacts were recorded for location using a GPS receiver and habitat type noted.

Results

Post Stocking Monitoring and Assessment

Field surveys on the lower Colorado River in 2006 yielded 12,612 fish (Tables 4 & 5). Bluegill sunfish *Lepomis macrochirus* was the most abundant fish overall (22.5%, Table 5), followed by largemouth bass *Micropterus salmoides* (19.3%), redear sunfish *L. microlophus* (18.2%), common carp *Cyprinus carpio* (11.8%), threadfin shad *Dorosoma* *petenense*, and unidentified sunfish *Lepomis sp*. (5.5% each), razorback sucker *Xyrauchen texanus* (5.4%), channel catfish *Ictalurus punctatus* (2.2%), striped bass *Morone saxatilis* (2.0%), flathead catfish *Pylodictis olivaris* (1.7%), blue tilapia *Oreochromis aureus* (1.4%), warmouth *L. gulosus* (1.3%), smallmouth bass *M. dolomieu* and redbelly tilapia *Tilapia zillii* (1.1% each). Other species contributed less than one percent each to the total catch.

Sunfishes (genus *Lepomis*) dominated the overall catch in all USBR administrative divisions (Fig. 3), but were especially dominant in the Imperial division (54.2%). Other differences in fish catch among divisions appear minor except for the larger proportion of razorback sucker catch in the Havasu and Palo Verde divisions reflecting their status as stocking areas.

CPUE among administrative divisions and sampling gear demonstrate the strengths and weaknesses of the two types of sampling gears used. In the lentic conditions of the Imperial Division, trammel netting is the most efficient relative to other divisions, while electrofishing is less effective potentially due to a lack of water clarity (Fig. 2). The Palo Verde Division is dominated by lotic conditions; however, trammel netting is relatively efficient and electrofishing is not. This is due to the focus on backwaters for surveys in this division. Electrofishing is relatively more efficient in other divisions that occur in lotic portions of the Colorado River (Havasu and Cibola divisions).

Razorback sucker encounters numbered 679, representing 669 individual fish. We processed 598 fish for tag information, gender, sexual condition, health, and length, and 474 for weight (Tables 6 & 7). Unmarked fish were implanted with PIT tags and released near their capture site[4]. Seventy-one fish were released unprocessed because we strive to avoid unnecessary stresses and wanted to ensure viability of all fish when exceptionally large catches were encountered. Total length averaged 37.9 cm (range 28.3 – 62.0). Sex ratios were 82 female, 175 male, 285 juvenile, and 56 unknown. There were six mortalities. All of these razorback suckers are thought to be repatriated fish because 1) most contained wire hatchery tags, 2) 48% were juveniles, and 3) growth rate data suggest that a 37.9 cm razorback sucker is 2 to 3 years old (Marsh et al. 2005).

[4] Five fish captured in A-7 were released without PIT tags due to unavailability of tags.

The Native Fishes Work Group database maintained by ASU reports a total 6,115 PIT tagged razorback suckers released into the LCR[5] since 1993 (Table 8). However, no razorback sucker released with a PIT tagged prior to November 2004 (when partial PIT tagging of release batches was initiated) has been captured. Since then, 4,299 PIT tagged razorback suckers have been released into A-7 or A-10 through 2006 (4,308 releases have been noted in AZGFD stocking records, so there is a minor and inconsequential discrepancy of nine fish). There have been 273 captures of these tags representing 253 fish. A total of 53 captures were initially released into A-7 and 220 were released into A-10. The great majority of these captures occur within a few months post-release (Fig. 5), and only two fish from each release site have been captured after more than one year at large.

Most razorback sucker capture locations coincided with recent stocking locations. Only four fish released within the stocking zone were captured outside that zone; two in or near Hippie Hole (RM 99, AZ side of the river) one in Bonnie’s Kitchen (RM 99, CA side), and one adult female (57 cm) captured upstream from Imperial Dam (RM 50). Within the stocking zone, one fish was captured upstream of the stocking site at Squatter Backwater (RM 124). The remaining fish were captured in or near the stocking sites. Twenty razorback suckers were captured in the vicinity of Imperial National Wildlife Refuge, including three fish at Fisher’s Landing (RM 56) and 17 fish at Martinez Lake (RM 57). All of these fish originated from a release of PIT tagged fish into Martinez Lake in January 2006. A single trip to Parker Strip in December yielded 44 razorback suckers. Two fish were marked with PIT tags and 29 had wire tags, indicating that they had been released in September and November 2006 at Buckskin Mountain State Park. Two razorback suckers were also encountered at Hippie Hole a few weeks after their release into Palo Verde Recreation Area (USFWS unpublished data), approximately one mile upstream.

In general, no build-up of stocked fish is apparent from repeated surveys of the stocking backwaters (Figs. 6, 7, & 8), although the results from A-10 are inconclusive. Electrofishing CPUE in upper and lower sections of A-10 suggests a slight accumulation,

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[5] Data exclude PIT tagged razorback suckers held in isolated waters such as Cibola High Levee Pond and Senator Wash Reservoir; at which separate razorback sucker projects are ongoing.

but electrofishing efforts have increasingly targeted schools of razorback sucker in an effort to reduce the use of trammel nets in these intensively stocked backwaters. In contrast, trammel netting efforts have failed to show a build-up, but recent low CPUE for A-10 Upper (October 2006) and A-10 Lower (October and November 2006) represent trips in which only two experimental trammel nets (one floating and one sinking) were deployed. Typical net sets include at least four sinking trammel nets. Therefore these low values may represent the reduced probability of encountering a school of fish with only two nets.

Only five razorback suckers were captured and recaptured in 2006 (excluding 5, short-term recaptures). Three fish were captured and recaptured in A-10 Upper, one was captured and recaptured in A-10 lower, and one was captured in A-10 Upper and recaptured in A-10 lower. The low number of recaptures precluded quantitative population estimation in 2006.

Additional captures of native fish included one striped mullet *Mugil cephalus*, comprising less than 0.01% of total catch. This fish was captured by trammel netting at the C-5 backwater in Palo Verde Division near Blythe, CA. It was not tagged because the species has no protected status and is a “catadromous, cosmopolitan, coastal marine species” (Berra 2001). Striped mullet are common in the Yuma Division, below Laguna Dam (Marsh & Minckley 1985), but have been rarely observed in the reaches upstream (Minckley 1979).

Analysis of hatchery-implanted wire tag retention has indicated that the left pectoral implantation, used on fish released in the lower section of A-10 backwater, may result in high rates of tag loss or lack of readability. For example, a release of 2,360 razorback suckers in September 2006 included individuals with both PIT and wire tags; however, comparisons of catch in October and December 2006 with PIT tag information provided by USBR indicates that up to 24% of wire tags implanted into the left pectoral were lost or rendered undetectable within three months post release.

Piscivorous Fishes

In A-10 backwater, 2 to 6 simultaneous gill nets fished for a total of 245.5 hrs captured two flathead catfish (67.5 cm, 6 kg; 88.0 cm, 10 kg), one common carp, and one razorback sucker (processed under standard monitoring protocols and released). The larger of the flathead catfish was dead in the net while the smaller was marked and released. Jug lines captured only one largemouth bass, which was moribund. Fish contained no detectable PIT tags or metal. Subsequent monitoring in A-10 has not encountered the one marked flathead catfish.

In A-7, four gill nets fished for a total of 160 hrs captured one flathead catfish, two common carp, and 20 large blue tilapia. The flathead catfish contained no detectable PIT tags or metal.

Avian predation

Database Avian Notation Analysis.--Yearly proportion of catch with evidence of avian predation decreased: 2003- 35%, 2004- 33%, 2005- 25%, and 2006- 21%. Chi Square Homogeneity indicates an unequal distribution across years (X^2 = 10.445, df = 3, p-value = 0.015) and therefore the decreasing trend is significant. Proportion of catch indicates an increase in predation attempts during winter months (Fig. 9). There was a significant difference between the two sections of A-10 backwater in proportion of catch with evidence of avian predation: 31% in the upper section and 12% in the lower (X^2 [Yates' corrected] = 29.75, df = 1, p-value < 0.000). As a whole, A-10 backwater (27%) significantly differed from A-7 (37%) and other localities (21%) in respect to proportion of catch (X^2 = 15.531, df = 2, p-value < 0.001). Overall, 27% of all razorback sucker captures have displayed markings consistent with avian predation. Of the 338 fish captured with avian wounds, 53 were PIT tagged when stocked. At time of capture, these fish were at large an average of 111 days. Minimum at large days was 16 with 21 fish (40%) at large for 43 days or less.

Surface Netting Model.--Preliminary data analyses support an inverse logarithmic relationship between depth index and time since stocking (Fig. 10). Currently available data are few, therefore further analysis will be reported in 2007.

Raceway Imagery.--Control and experimental fish were similar in mean initial TL: 24.6 cm (SE 1.0) and 24.3 mm (SE 0.9), respectively. Fish exhibited similar growth across treatments and final mean lengths were 27.0 cm (SE 1.1) and 26.3 mm (SE 0.8), respectively. Full analysis of raceway digital images is not yet complete. Preliminary analyses indicate that raceway depth may not be sufficient for discriminating a change in surfacing behavior. A notable observation was that during the starving phase, fish behaved more erratically, likely searching for food. During this period, fish were more often photographed exploring all areas of the raceway while they behaved rather predictably during regular feeding.

Subsurface Pond Feeder: As the fish involved with the subsurface feeding investigation have not been stocked at the time of this report, there are little data to include here. Anecdotally, hatchery personnel reported that the experimental fish, while often visible when feeding prior to installation, were rarely within view once subsurface feeding commenced. This may be an indicator that the fish were spending less time near the surface now that they received their food lower in the water column. Further results will be reported in 2007.

Sonic and Radio Telemetry

Final status of 24 telemetry-tagged razorback suckers is summarized in Table 9. Overall, 50% (6) of the fish released into A-7 backwater dispersed during the study. Initially, two fish dispersed within 20-d post release. Additional fish continued to exit the backwater over the next three weeks, and all fish that eventually exited the backwater had done so by 50-d post-release (Fig. 11). Fish that exited A-7 backwater were never contacted in any subsequent survey, despite coverage of the entire main channel and adjacent backwater habitat. The remaining six fish that did not disperse all died within the backwater. These mortalities were confirmed by recovery of telemetric tags via SCUBA.

In contrast to A-7, no dispersal was detected from A-10 backwater. All fish released there remained within A-10 and were contacted regularly throughout the study. Of the 12 fish originally released, two telemetric tags were nonfunctional for unknown reasons immediately following release. These fish were not contacted in any survey and thus were omitted from analysis. The 10 functionally tagged fish released within A-10 each had one of three different outcomes. At the end of the study (December 2006), six fish were confirmed dead and their tags were recovered from the backwater. Of the four fish not recovered, two were confirmed alive while the fate of the last two fish was unknown. The minimum number of surviving fish within each backwater dwindled throughout the study, and did so more rapidly in A-7 backwater than in A-10 (Fig. 12). This minimum value represents the number of fish originally released in each backwater (12) less the combined number fish that dispersed or were recovered from the backwater.

Discussion

Post Stocking Monitoring and Assessment

Long-term survival of razorback suckers stocked into the lower Colorado River appears to be extremely low. Neither backwater release location in the stocking zone is a showing long-term increase in number of fish. Although more fish released in A-10 have been captured, the long-term survival appears similar -- both A-10 and A-7 releases have just two captures of fish at large for more than one year. Effort was concentrated in the stocking zone and therefore razorback suckers were less likely to be captured elsewhere. However, sampling over the past four years as well as CPUE from the past year supports the paucity of captures in other locations as being based on a lack of fish, not a lack of effort.

There is still the potential of long-term survival, albeit small, demonstrated by the recapture of fish at large for more than 500 days. These recaptures represent the longest days at large possible for fish derived from partially PIT tagged batches released into A-7 and A-10. If these fish continue to be encountered in 2007, quantitative estimates of overall survivorship may be possible. Continued monitoring of A-10 will resolve the ambiguity in the CPUE data, and monitoring of water chemistry during the hottest summer months may shed light on possible mortality issues there. Additional stocking sites (e.g. Buckskin State Park, Parker Strip), and the initiation of bonytail stockings in late 2006 may provide opportunities for new insights, although survivorship is unlikely to improve.

Additional sample data and observations of post-stocking mortality suggest the need for thermal acclimation studies, but no such project is currently under consideration. For example, a stocking of 2,360 razorback suckers into A-10 lower in September 2006 may have been impacted by a 5°C temperature difference between the hatchery truck water and the receiving water. Buckets of water from A-10 were used to equalize the temperatures over the course of about one hour. Recommended acclimation time for such a temperature difference is about 2.5 hours (Stickney 1983; see also Piper et al. 1982). Individuals from this relatively large group of fish have been underrepresented in post-stocking surveys, suggesting that survivorship was below average. The feasibility of acclimation studies will be assessed in 2007 based on stocking dates, stocking numbers, ongoing experiments (e.g. avian predation and piscivory) and cooperation of parties involved (e.g. Arizona Game and Fish Department and USBR).

Piscivorous Fishes

Jug lines and gill nets were either ineffective at catching large flathead catfish, or abundance of flathead catfish is relatively low in A-10 and A-7 backwaters. Low abundance seems likely because routine monitoring in 2006 also failed to encounter a large number of flathead catfish (one in A-10 and 5 in A-7). Although flathead catfish is the largest piscivorous fish in the lower Colorado River, other predacious fishes such as largemouth bass may have a greater impact on overall razorback sucker mortality. Similar attempts to assess largemouth bass abundance and their impact on razorback sucker survival in the stocking backwaters are currently under way.

Avian predation

Evidence of avian predation through database analysis suggested a reducing trend from 2003 to 2006. Data also indicated that less avian predation occurs in A-10 backwater than in A-7. Taking these observations into account and in light of the fact that the primary stocking site changed from A-7 to A-10 in February 2005, the temporal trend is possibly explained by the swamping of 2005-2006 captures by fish from A-10. Evidence also indicates that other capture locations (not A-10 or A-7) reveal the lowest proportion of catch with avian wounds. This should be interpreted with caution because many of these captures were in the near vicinity of A-7 and A-10, but are grouped here for contrast. A-10 upper appears to have a higher level of avian predation than A-10 lower, but this may simply be due to the fact that A-10 upper has been stocked in winter, when avian predators are present, whereas A-10 lower has not. The size of the sub-sample of wounded fish that had been PIT tagged at the time of stocking (53 fish) suggests that avian predation may occur soon after stocking.

The surface netting model provides data that support the hypothesis of a window of vulnerability when stocked fish occupy the upper part of the water column, but this relationship to habituation may be more complex. The decreasing depth trend was evident, but considerable variation in DI exists and other variables must be taken into account including water temperature and chemistry, season, location, proximity to shore or cover, fish gender and condition, and effects of schooling. The assumption that a fish's entanglement site in the net represents its intended trajectory may not be valid because stocked cohorts generally form dense schools and these schools also incorporate fish from other cohorts. Naïve fish may be attracted to the sight (or movements) of a con-specific trapped in the net and may then become entangled. All of these factors will likely be included in a more complex mathematical model to remove some of the effects while isolating depth and time since stocking.

Observations from the raceway imagery experiment, though inconclusive, lend support to an hypothesis of surface vulnerability post-stocking. In the raceway, fish behaved predictably by swimming near the substrate and remaining hidden unless food was available. Once the food source was removed, the daily patterns changed and fish attempted to seek out food in other locations, swimming at shallower depths and exploring the sides of the raceway. If the fish were allowed to find food in a new location, it may be expected that a new pattern would develop. When fish are stocked, a similar scenario may occur where fish find themselves in a backwater and have yet discovered the food source. Initially, the fish may search the surface for food, as they were trained to do in the hatchery. This behavior combined with the affinity to school with stocking cohorts may exacerbate the risk of avian predation.

Sonic and Radio Telemetry

Few long-term captures of stocked razorback suckers likely results from a combination of both high levels of dispersal and low survival. For A-7 backwater, with continuously open connection to the main channel, data suggests that most fish leave the backwater and utilize main channel. Further, no fish that exited A-7 was ever contacted again within the release site or any other backwater habitat. Despite identical results from a similar study employing radio telemetric tags from our earlier work (e.g., Lee et al. 2006), extensive trammel netting (Marsh unpub. data) and published results (e.g., Gurtin et al. 2003; Mueller et al. 2003; Slaughter et al. 2002) report that razorback sucker utilize backwater habitats of the lower Colorado River. Limitations in detecting fish within backwaters may result from stocking too few telemetric fish into a large, complex habitat. Regardless, fish likely move between connected backwaters and the main channel. By contrast, stocking fish in backwaters with only intermittent connections via culverts like A-10 may avoid dispersal altogether. Results here and from previous radio telemetry both report that no fish exited A-10. A remote PIT tag scanner monitoring the main A-10 culvert consistently showed low dispersal. Estimates of dispersal from A-10 approximate 2.5% of stocked fish (Schooley et al. 2007).

Unlike differential dispersal, long-term mortality is similar between the two backwater types (i.e., permanently vs. intermittently connected with the main channel). Confirmed mortality from recovered tags indicated 50% of stocked fish from both A-10 and A-7 died within the release backwater. These results are interesting for several reasons. Our recent work indicates connected backwaters of this stream reach (including A-7) harbor higher numbers of large predatory fishes such as flathead catfish and striped bass. Second, the uniform depth and steep banks of A-10 might suggest differences in avian predation pressures associated with shallow beaches. However, the ultimate fate of 50% (6) of fish from A-7 is unknown and mortality could be much higher than we suggest. Further investigations of predation and other sources of mortality such as poor water quality or disease are required. Multiple causes of mortality make it difficult to determine the relative suitability for razorback suckers of continuously connected A-7 versus intermittently connected A-10 complex. Despite similar rates of ultimate survival, these telemetric tagged fish showed that short-term survival may be higher in A-10 than A-7. Considering the high dispersal and increased likelihood of encountering aquatic predators in the main channel, A-10 may provide a more suitable stocking site for a captive population.

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Table 1. Razorback survey trip report numbers, dates, and locations on the lower Colorado River, 2006.

Trip Report	Trip Dates	Sampling Locations
2-1	06 – 13 Jan 2006	Main Channel (Imperial), Adobe Lake, Taylor Lake, Island Lake
2-2	09 – 17 Feb 2006	Imperial NWR, Martinez Lake, Ferguson Lake, Fisher's Landing, Main Channel (Imperial)
2-3	28 Feb – 9 Mar 2006	C-5, C-7 and C-10 Backwaters, A-10 Upper and Lower Backwaters, A-7 Upper Backwater
2-4	11- 20 Apr 2006	Main Channel (Imperial), CS-1, CB-2, CB-3, CB-4, CB-5, and CB-6 Backwaters, CB-10 Squaw Lake
2-5	2 – 11 May 2006	C-5 and C-7 Backwaters, A-10 Upper and Lower Backwaters, A-7 Upper Backwater, Sandy Cove, Main Channel (Cibola)
2-6	9 – 13 Oct and 23 - 27 Oct 2006	C-5 and C-7 Backwaters, A-10 Upper and Lower Backwaters, A-7 Upper Backwater, Sandy Cove
2-7	6-9 Nov, 28 Nov - 2 Dec 2006	Cibola NWR (Walter's Camp), Oxbow Recreational Area, Bonnie's Kitchen, Squatter Backwater, C-7 and C-10 Backwaters, A-10 Upper and Lower Backwaters, Main Channel (Palo Verde)
2-8	11 – 15 Dec 2006	Main Channel (Parker Strip)

Table 2. Razorback stockings below Parker Dam[6], lower Colorado River, since 2000 by year and location.

Year	Stocking Location	No. Stocked
2000	A-7 Upper backwater	2,990
	Imperial Reservoir	37
	Lower River, Unknown location	45
	River Island, Buckskin Mountain State Park	1,308
2001	A-7 Upper Backwater	4,388
	Imperial Reservoir	37
2002	A-7 Upper Backwater	15,548
2003	A-7 Upper Backwater	14,058
	Imperial NWR, Main Channel	12
2004	A-7 Upper Backwater	5,212
2005	A-10 Upper Backwater	2,161
	A-7 Upper Backwater	2,143
2006	A-10 Lower Backwater	4,841
	A-10 Upper Backwater	790
	A-7 Upper Backwater	1,642
	Buckskin Mountain State Park	1,659
	Main Channel (from Imperial Duck Ponds)	30
	Martinez Lake	727
	River Island, Buckskin Mountain State Park	2,530
Total		**60,158**

[6] Stocking data are compiled from numerous sources, which are not listed in this report.

Table 3. Summary of voucher specimens (field-collected, fixed, preserved and deposited into Arizona State University Collections) collected from the lower Colorado River, 2006.

Species	No. of Vouchers
Ictalurus punctatus	1
Lepomis gulosus	2
Lepomis macrochirus	2
Micropterus salmoides	3
Morone saxatilis	8
Pomoxis nigromaculatus	3
Tilapia sp.	1
Tilapia zillii	1

Table 4. Total effort and catch by method amongst four USBR divisions sampled in the lower Colorado River, 2006.

	2006 Effort and Catch Totals			
	Electrofishing		Trammel Netting	
USBR Division	Seconds	Fish	Nets-Hours	Fish
Cibola	5,081	534	281.7	315
Imperial	40,309	2,503	1320.8	2,797
Palo Verde	52,138	3,099	1581.7	2,602
Havasu	6,011	539	308.9	223
TOTALS	103,539	6,675	3,493.7	5,937

Table 5. Total captures and percentage of catch by species for trammel netting (TN) and electrofishing (EF) in the lower Colorado River, 2006.

Species	TN	%TN	EF	%EF	Total	%Total
Ameiurus natalis	14	0.2%	0	0.0%	14	0.1%
Carassius auratus	3	0.1%	4	0.1%	7	0.1%
Cyprinus carpio	849	14.3%	633	9.5%	1,482	11.8%
Dorosoma petenense	1	0.0%	687	10.3%	688	5.5%
Ictalurus punctatus	190	3.2%	83	1.2%	273	2.2%
Lepomis cyanellus	1	0.0%	47	0.7%	48	0.4%
Lepomis gulosus	59	1.0%	108	1.6%	167	1.3%
Lepomis macrochirus	1,786	30.1%	1,058	15.9%	2,844	22.5%
Lepomis microlophus	1,404	23.6%	892	13.4%	2,296	18.2%
Lepomis sp.[7]	0	0.0%	688	10.3%	688	5.5%
Micropterus dolomieu	49	0.8%	90	1.3%	139	1.1%
Micropterus salmoides	529	8.9%	1,901	28.5%	2,430	19.3%
Morone saxatilis	113	1.9%	138	2.1%	251	2.0%
Mugil cephalus	1	<0.1%	0	0.0%	1	<0.1%
Oreochromis aureus	150	2.5%	21	0.3%	171	1.4%
Pomoxis nigromaculatus	42	0.7%	27	0.4%	69	0.5%
Pylodictis olivaris	149	2.5%	63	0.9%	212	1.7%
Tilapia sp.[8]	10	0.2%	1	0.0%	11	0.1%
Tilapia zillii	97	1.6%	45	0.7%	142	1.1%
Xyrauchen texanus	490	8.3%	189	2.8%	679	5.4%
Totals	**5,937**		**6,675**		**12,612**	

[7] Differentiation between young-of-year *Lepomis macrochirus* and *L. microlophus* can be difficult. Therefore, the two species are grouped in the category (*Lepomis* sp.). Whenever possible, young-of year are categorized by species.

[8] On the lower Colorado River, feral populations variously derived from *Tilapia mariae, T. zilli, Oreochromis mossambicus*, and *O. aureus* can be found (Costa-Pierce, 2003). Discrimination among species can be problematic, and "*Tilapia* sp." is used when the species is uncertain.

Table 6. Razorback sucker capture data summary, lower Colorado River, 2006.

General Data

Total capture events:	608	Excludes 71 fish captured but not processed.
Individual fish marked with PIT tag:	367	PIT tagged by ASU in 2006.
Short-term recaptures[9]:	5	
Recaptures[10]:	225	
Fish released without PIT tag	5	
Mortalities	6	Includes 1 salvaged carcass.

Gender Ratios (598 records)

Female:	82	14%
Male:	175	29%
Juvenile:	285	48%
Unknown[11]:	56	9%

Hatchery / Wire Tags

Detectable wire tags	86%	499 of 583 fish scanned (15 fish not scanned)
- Left Pectoral	15.8%	79 of 499 detected
- Right Pectoral	5.8%	29 of 499 detected
- Left Dorsal	16.2%	81 of 499 detected
- Right Caudal Peduncle	62.1%	310 of 499 detected

Size Data (cm)

Mean Total Length:	38.0	608 records
Minimum Total Length:	28.3	
Maximum Total Length:	62.0	

Weight Data (g)

Mean Total Weight:	584	474 records
Minimum Total Weight:	214	
Maximum Total Weight:	1,818	

[9] Fish captured a second time during the same site visit are referred to as "short term recaptures" (STR) to differentiate them from captures of fish marked during prior trips or by other investigators.
[10] This row refers to fish marked previously at any time, then captured in 2006.
[11] Razorback suckers classified as "unknown gender" are >40.0 cm TL and display no diagnostic secondary sexual characteristics. Fish <40.0 cm displaying no diagnostic secondary sexual characteristics are classified as "juvenile."

Table 7. Field notations for razorback suckers captured on the lower Colorado River (below Parker Dam), January to December 2006.

Total records:	608	608 records, but 598 individuals
External Parasites		
Total parasite notations:	23.8%	145 of 608
… from stocking zone:	25.7%	138 of 537
… from Parker Strip:	11.4%	5 of 44
… from other locations:	11.1%	3 of 27
Health Condition[12]		
Excellent	280	46.1%
Good	239	39.3%
Fair	58	9.5%
Poor	11	1.8% (4 held overnight died)
Mortality	2	0.3%
Sexual Condition		
Ripe Female:	3	41.2 cm mean TL
Ripe Male:	97	37.8 cm mean TL
Tuberculate Males:	113	
Mean TL (cm) by sex		
Female:	45.2	
Male:	38.3	
Juvenile:	35.0	
Unknown:	41.0	
Other notations		
"Scar," "descaled," "marks," or "frayed"	41.1%	250 of 608

[12] A categorical grading system was utilized to assign a health or condition level to each razorback sucker upon capture, see Schooley *et al.* (2006) for further explanation.

Table 8. Number of PIT tagged razorback suckers (captured, tagged, and released; or simply tagged and stocked) and total length (TL) data, lower Colorado River, 1993 - 2006. (adapted from C. Pacey, ASU, unpublished data)

Year	N	Avg. TL (cm)	SD	Min	Max
1993	53	42.1	4.863	36.3	61.5
1994	82	28.2	2.347	25.0	37.8
1995	513	31.7	5.844	25.0	59.2
1996	196	39.8	9.714	25.0	66.0
1998	80	44.1	5.935	36.0	55.3
1999	46	45.3	4.667	37.7	54.8
2000	7	28.6	1.204	27.2	30.2
2001	221	37.4	2.677	29.2	46.4
2002	10	41.7	11.481	26.4	56.0
2003	32	42.5	6.462	28.5	53.5
2004	91	40.0	7.262	26.5	57.5
2005	965	37.0	54.505	27.6	60.0
2006	3,819	35.7	48.638	30.5	62.0
Totals:	**6,115**	**36.0**		**25.0**	**66.0**

Table 9. Description, ultrasonic frequency and code, status and notes for 24 razorback sucker released on January 22, 2006 into A-7 and A-10 backwaters and subsequently tracked throughout the system.

fish no.	*TL(mm)*	*code*	*freq*	*release site*	*status*	*notes*
1	446	3334	79	A7	Recovered*	unable to recover in MC current by A7 inlet
2	497	3354	74	A7	Lost	unk, presume dispersal out of A7 by 20MAR06
3	482	3345	76	A7	Lost	unk, presume dispersal out of A7 by 20MAR06
4	466	3347	75	A7	Recovered	R-28AUG06
5	493	3356	73	A7	Recovered	R-7MAR06, re-implant A10L
6	457	3374	69	A7	Recovered	R-7MAR06
7	453	3367	70	A7	Lost	unk
8	530	3338	77	A7	Lost	unk, presume dispersal out of A7 by 20MAR06
9	425	3336	78	A7	Recovered	R-7MAR06
10	541	3376	69	A7	Lost	unk, presume dispersal out of A7 by 20MAR06
11	491	3365	71	A7	Recovered	R-28AUG06
12	482	3358	72	A7	Recovered	R-28AUG06
13	480	3368	70	A10	Recovered	from A10
14	435	3355	73	A10	Recovered	R-7MAR06, re-implant A10L and recovered 9OCT06
15	507	3344	76	A10	Live	alive in A10 at last contact
16	475	3375	69	A10	Recovered	from A10
17	467	3335	78	A10	Recovered	R-7MAR06, re-implant A10L
18	443	3337	77	A10	Lost	at large in A10
19	465	3333	79	A10	Lost	gone since release
20	488	3346	75	A10	Live	alive in A10 at last contact
21	509	3366	70	A10	Recovered	from A10
22	476	3364	71	A10	Lost	at large in A10
23	455	3348	74	A10	Lost	gone since release
24	426	3357	72	A10	Recovered	from A10

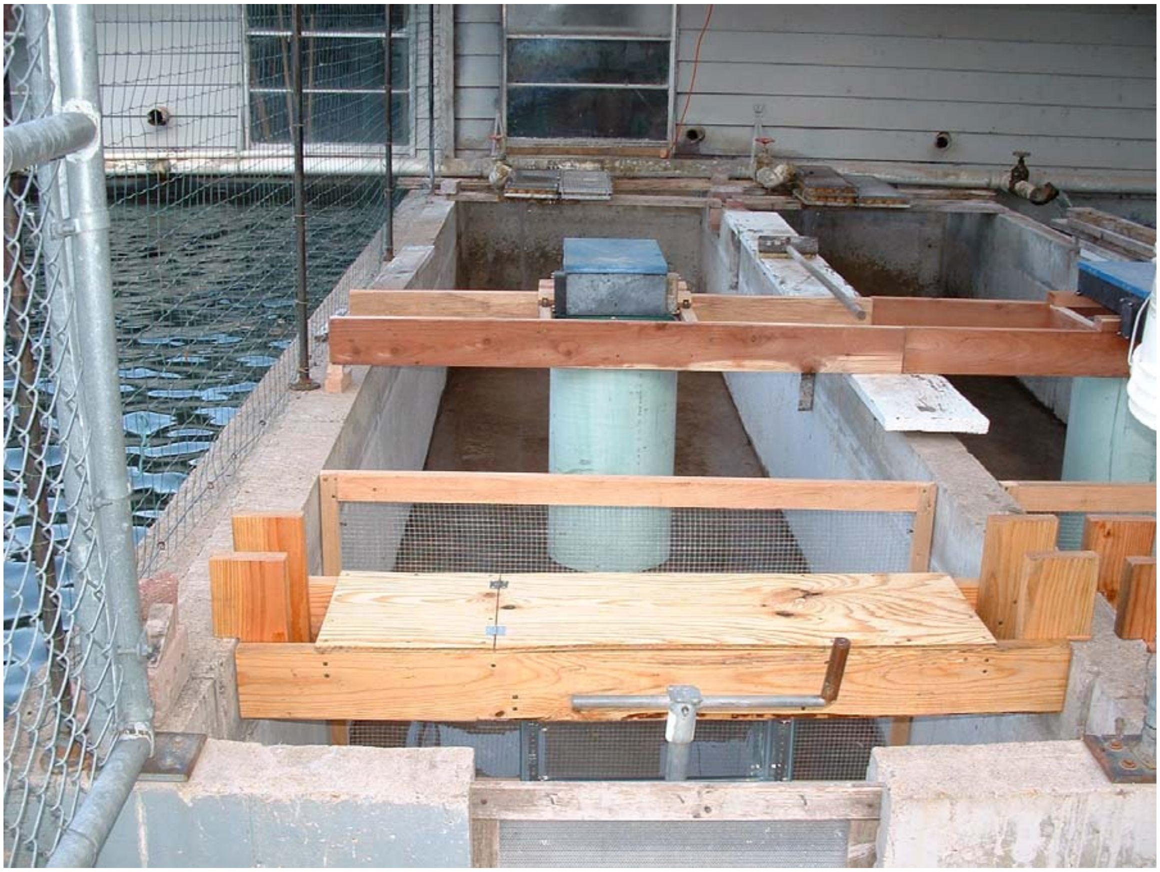


Fig. 1. Subsurface raceway feeding tube at Bubbling Ponds State Fish Hatchery, Cornville, Arizona, prior to filling and addition of fish. Food is distributed by automatic feeder into the tube and allowed to sink to the substrate, preventing consumption near the surface. Underwater imagery equipment is housed in the wooden apparatus in the foreground.

Fig. 2. Subsurface pond feeder deployed at Bubbling Ponds State Fish Hatchery, Cornville, Arizona, as viewed from the feeding catwalk. Exclusion consists of a PVC frame lined with 2.54-cm hexagonal mesh, galvanized poultry netting. Food is distributed to the surface (within the PVC) and is allowed to sink to a depth of 1.83 m before consumption is possible.

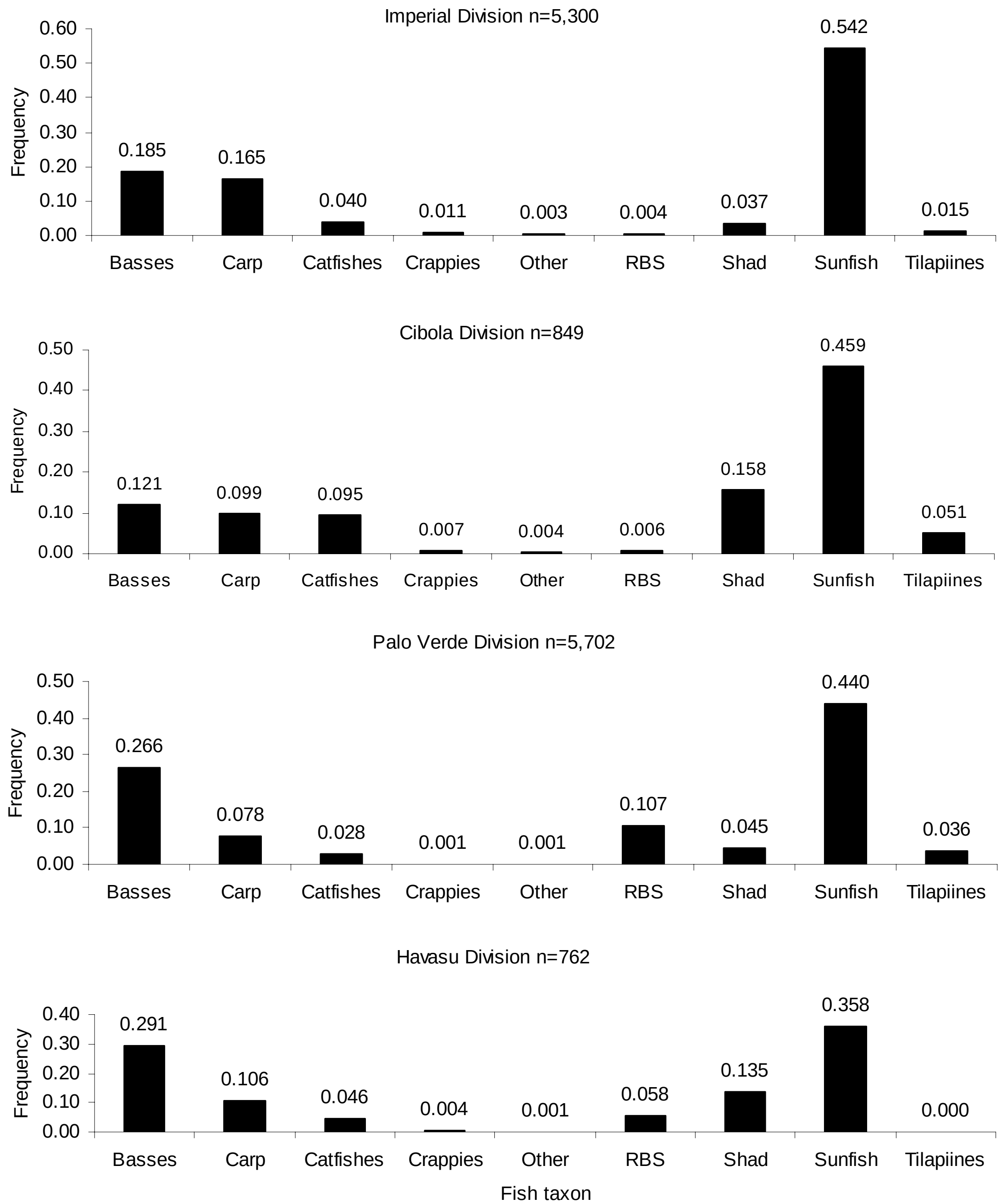
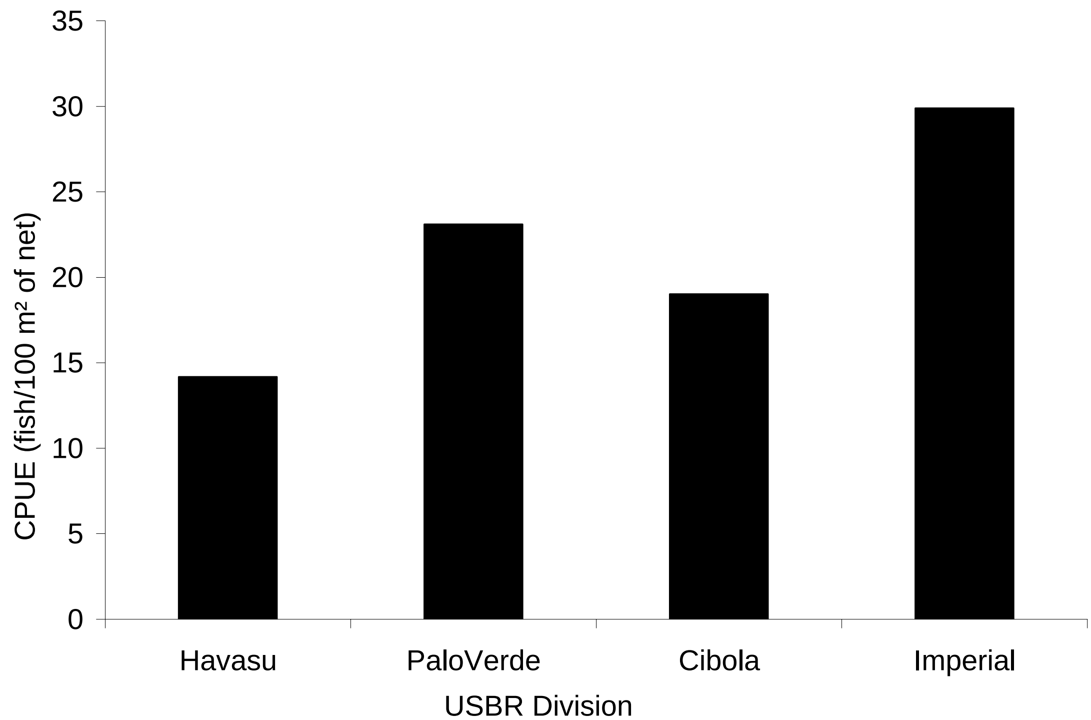


Fig. 3. Spatial distribution of fish taxa captured by electrofishing and trammel netting for four USBR administrative divisions in the lower Colorado River, 2006.



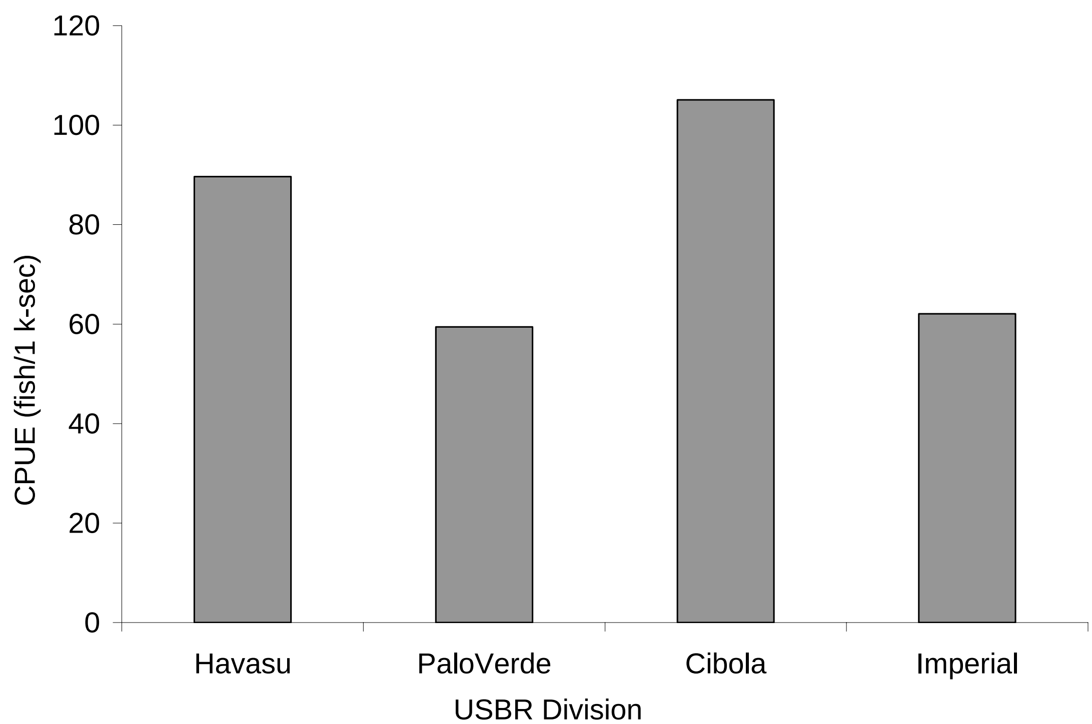


Fig. 4. Catch per unit effort for trammel netting (top) and electrofishing (bottom) for four USBR administrative divisions on the lower Colorado River, 2006.

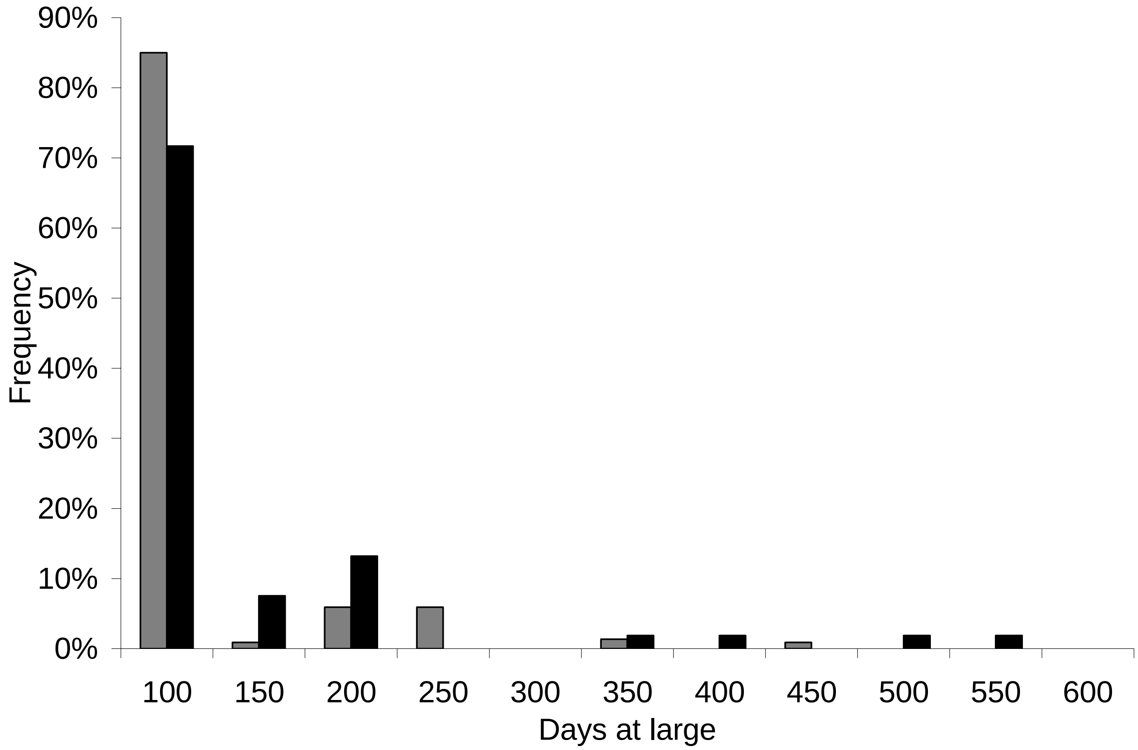


Fig. 5. Distribution of time at large for razorback sucker recaptures PIT tagged prior to release into A-7 Upper backwater (black) or A-10 Upper and Lower (grey), lower Colorado River, 2004-2006.

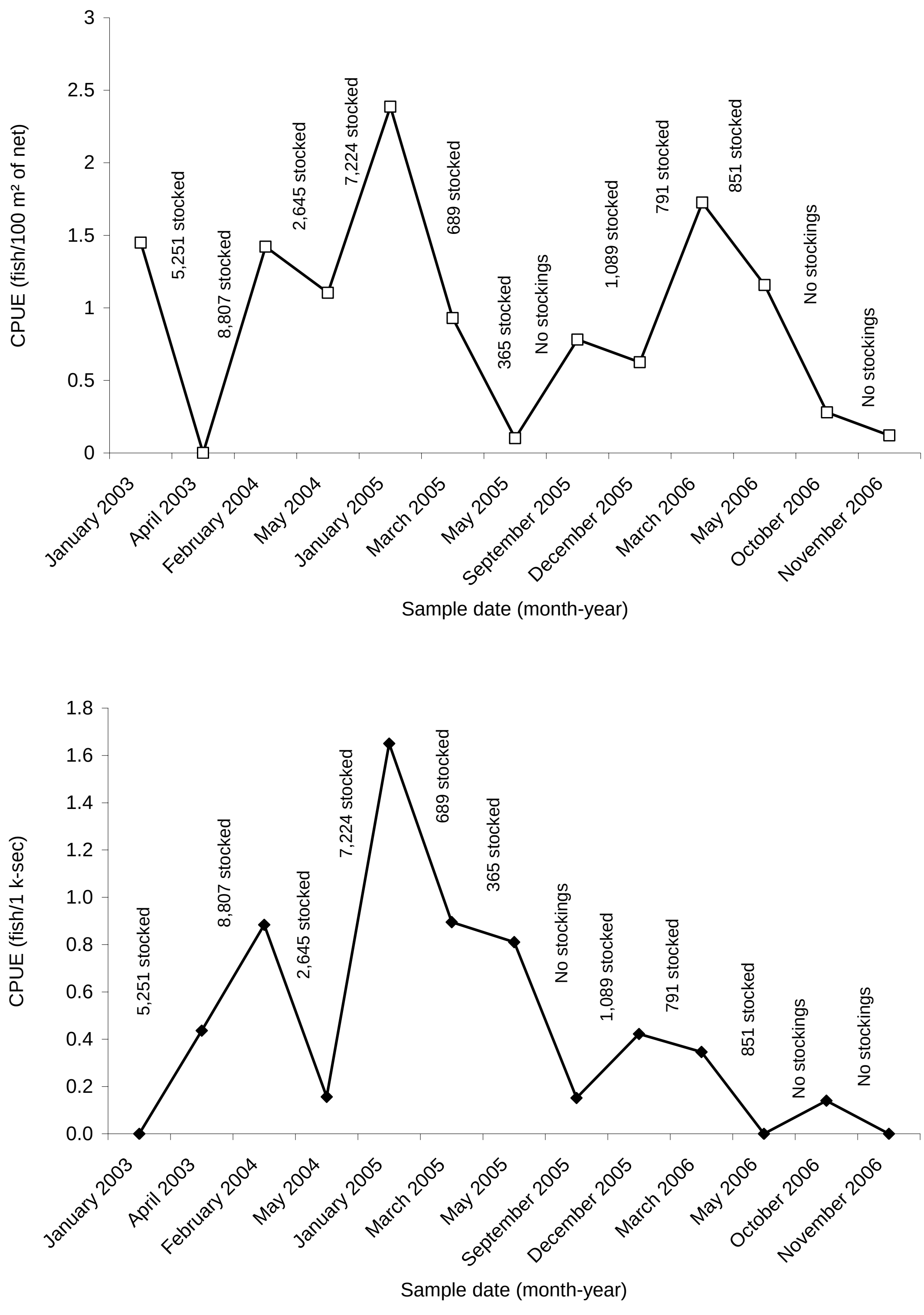
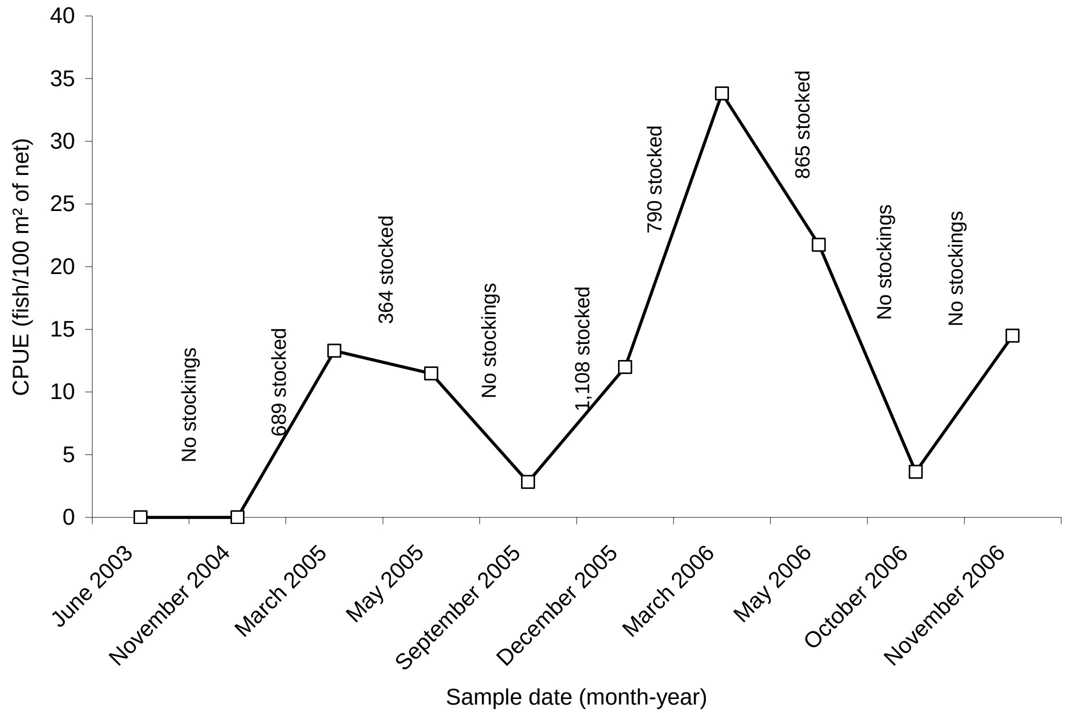


Fig. 6. Razorback sucker CPUE for trammel net (top) and electrofishing (bottom) effort in A-7 backwater and backwaters open to the river channel near A-7. Number of fish stocked represent cumulative stocking totals into A-7 between sampling dates.



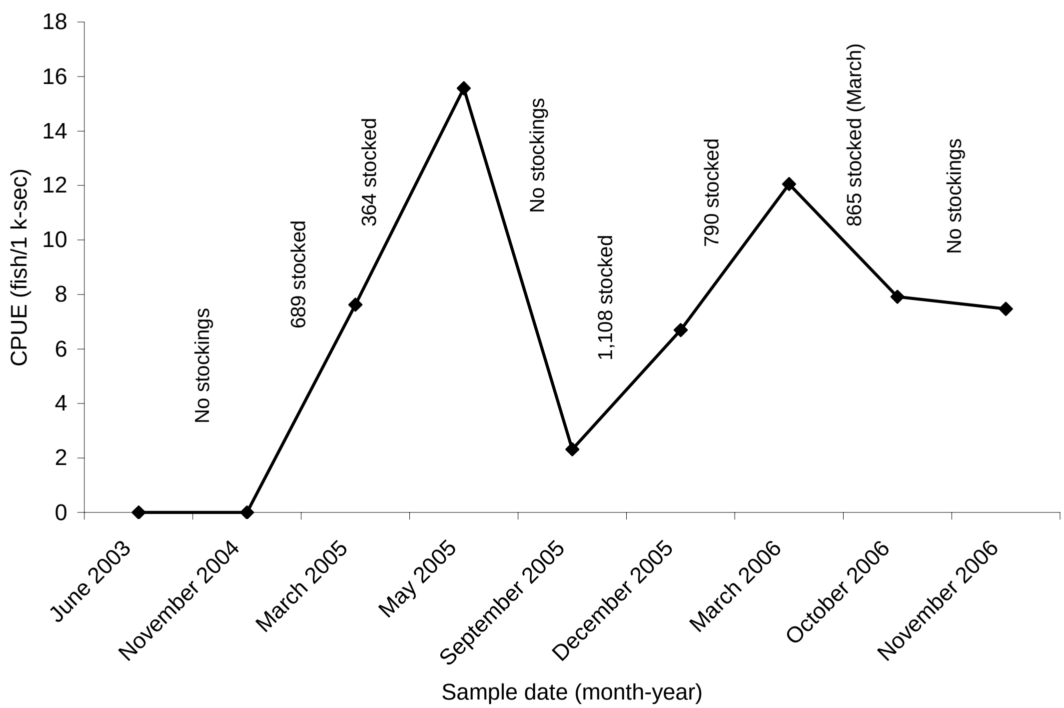
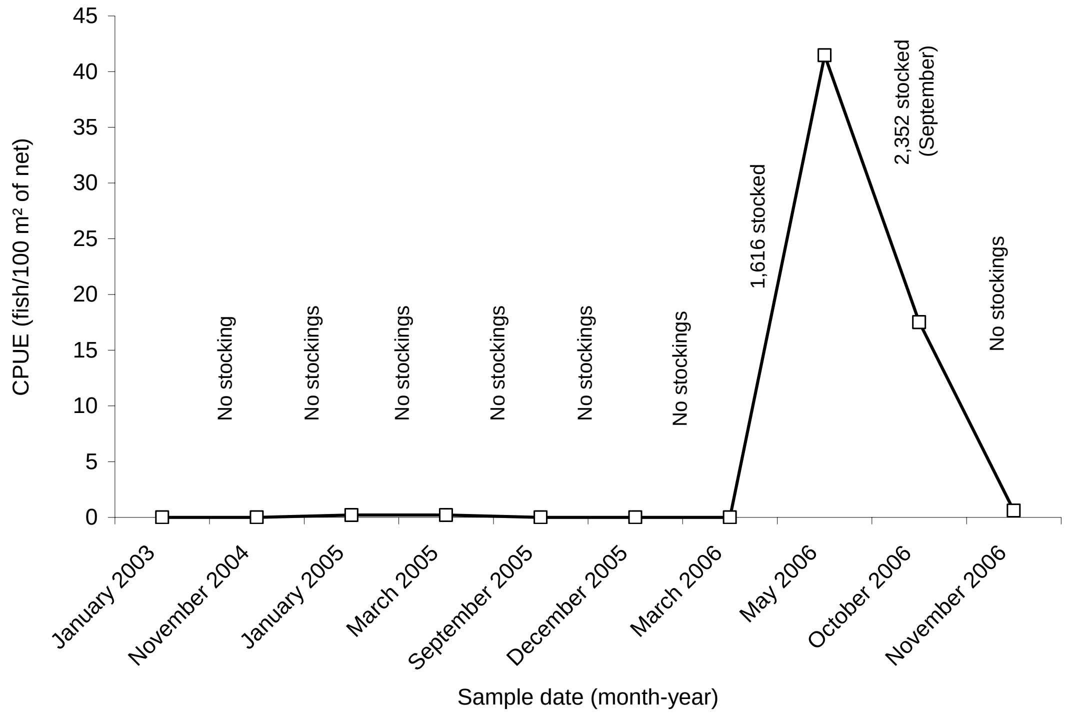


Fig. 7. Razorback sucker CPUE for trammel net (top) and electrofishing (bottom) effort in A-10 backwater (upper half). Number of fish stocked represent cumulative stocking totals into A-10 between sampling dates.



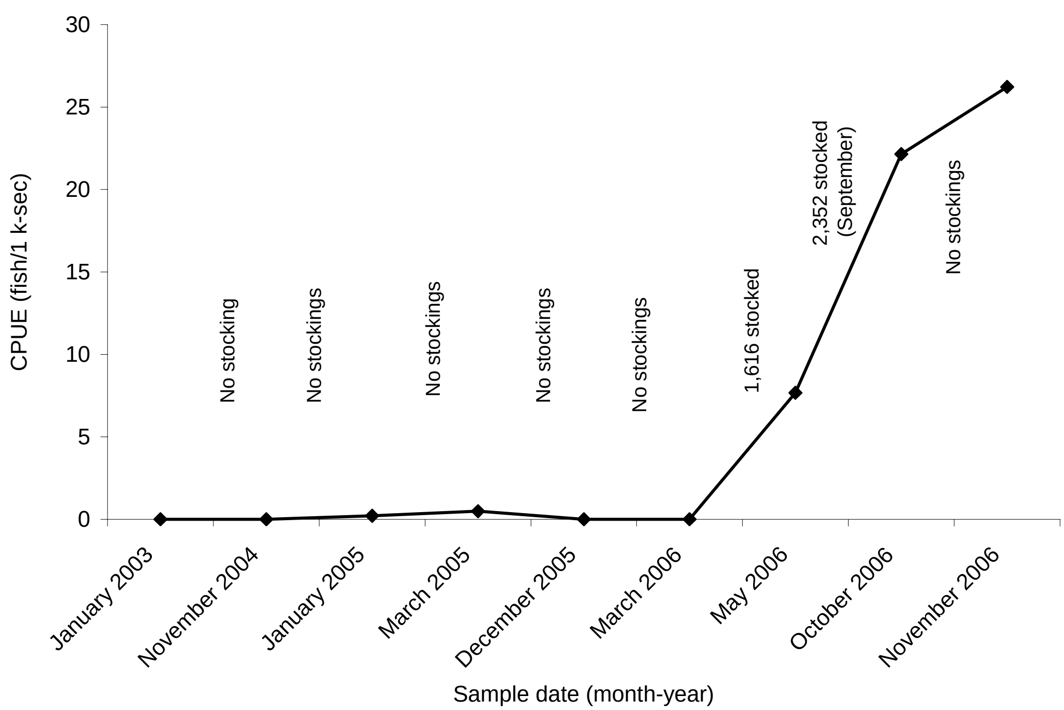


Fig. 8. Razorback sucker CPUE for trammel net (top) and electrofishing (bottom) effort in A-10 backwater (lower half). Number of fish stocked represent cumulative stocking totals into A-10 between sampling dates.

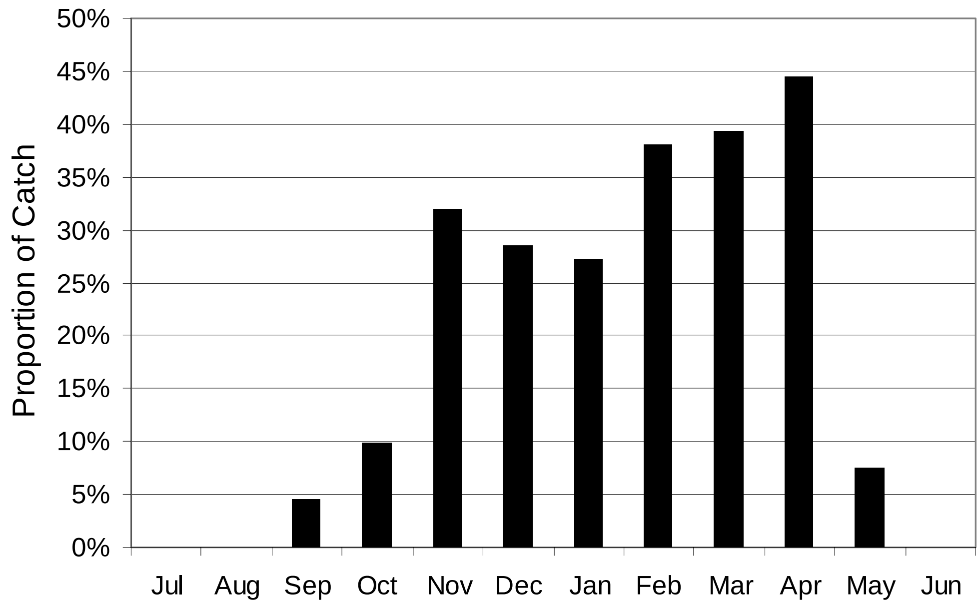


Fig. 9. Seasonal variation (Jan. 2003 – Dec. 2006) in proportion of catch for razorback sucker with physical wounds suggesting avian predation. No surveys occur during summer months. Data show a general increase in such wounds during winter-spring months when over-wintering migratory avian piscivores are abundant in the lower Colorado River, AZ-CA.

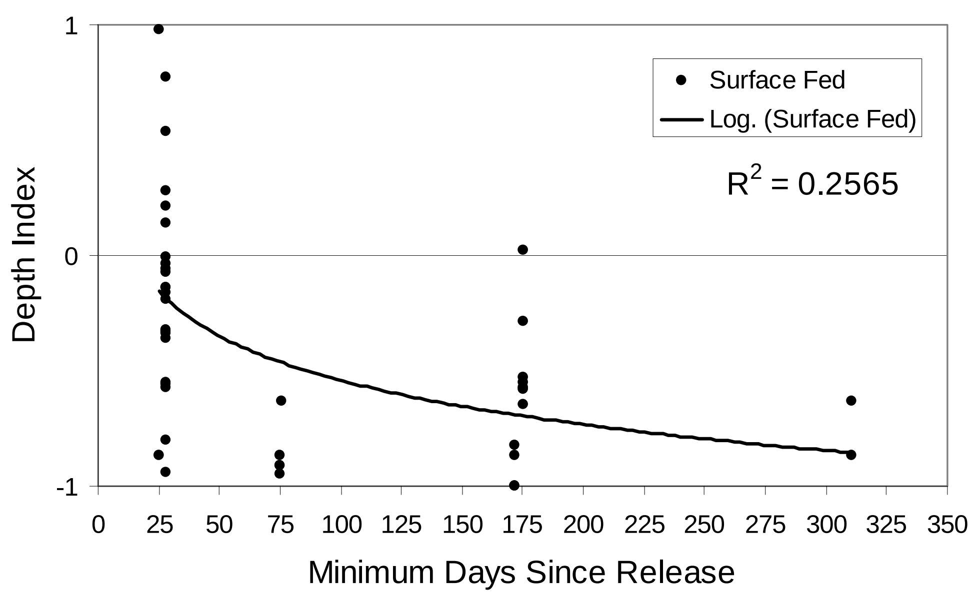


Fig. 10. Surface netting model output for razorback suckers captured in the lower Colorado River, AZ-CA. Data are few and preliminary, but a decreasing trend in depth preference over time since stocking appears evident.

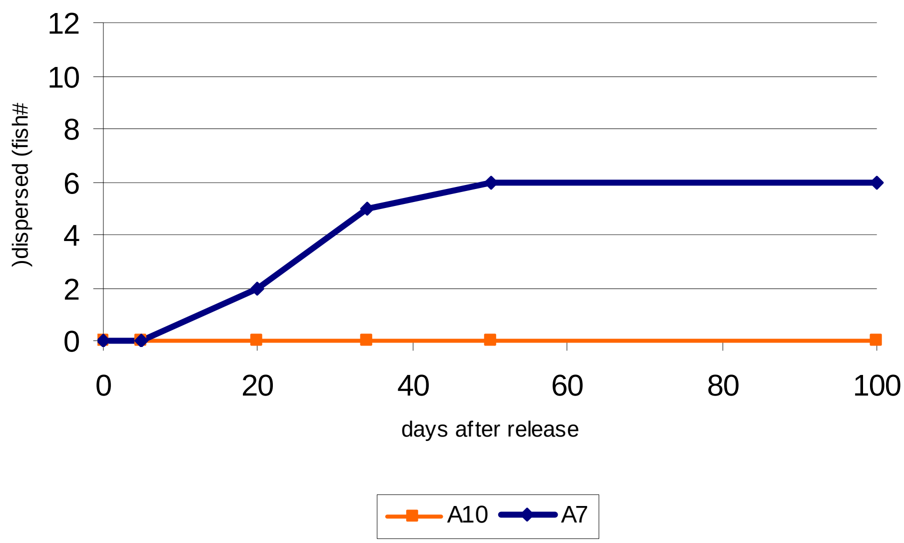


Fig. 11. Dispersal of telemetry-tagged razorback sucker from A-10 (intermittently – connected with the main channel) and open A-7 (continuously connected) backwaters 100 days after release.

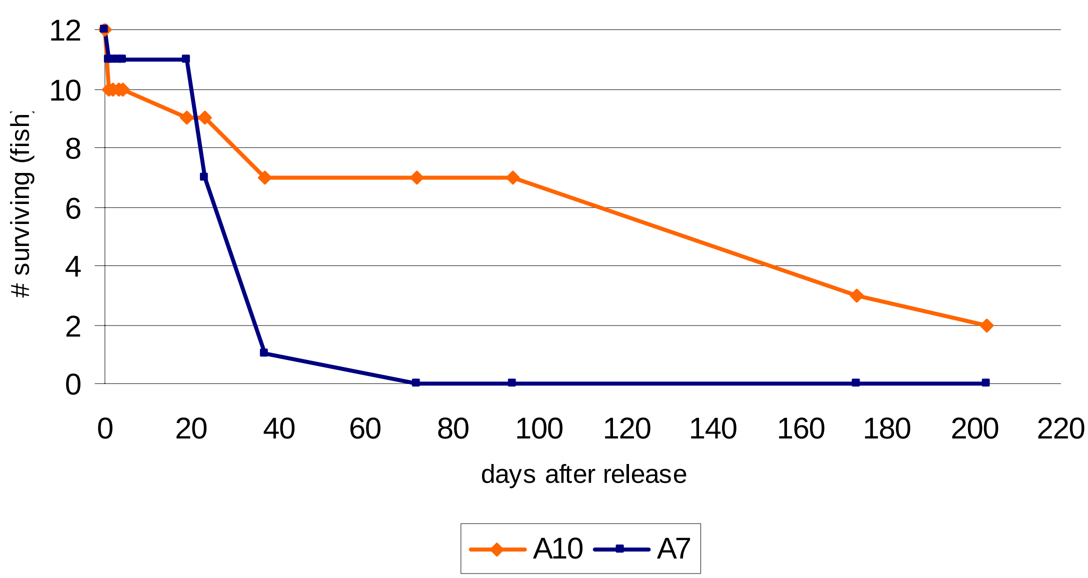


Fig. 12. Minimum number of surviving telemetry-tagged fish in A-7 and A-10 backwaters 200 days after release.